Article

Quality assurance and halal control points for the food industry

Lau, An Nee, Jamaludin, Mohd Hafiz and Soon, Jan Mei

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Introduction

Islam has outlined the rules and regulations for food preparation which suggest the source, process and people should conform to the principles of Islam faith (Samori *et al*., 2014) and covers the aspects of nurturing, slaughtering, storage, display, preparation, hygiene and sanitation. Halal (lawful) foods are free from any components that Muslims are prohibited from consuming. Most foods are halal except those that have been specifically prohibited by Qur'ānic guidance (Qur'an, 2:168, cited in Chandia, 2015) and the Sunnah (the life, actions and teachings of the Prophet Muhammad [Peace be upon him (PBUH)]) Riaz and Chaudry, 2004a). In addition, the Qur'ān verses regarding eating and food are "Toyyiban" – an Arabic word translated as "good or wholesome" (Hashimi *et al*., 2010).

Previous studies on understanding of halal concepts had been conducted among general Muslim consumers (Ambali and Bakar, 2014), respondents from higher education institutions (Yusuf and Ab Yajid, 2016), British Muslims (Jamal and Sharifuddin, 2015) and non-Muslims (Mathew *et al*., 2014). For Muslim consumers, halal food and drinks means products that meet the requirements as laid down by the Shariah law whereas for a non-Muslim consumer, it represents hygiene, cleanliness, quality and the safety of the product (Ambali and Bakar, 2014; Mathew *et al*., 2014).

Hygiene control and sanitation are the top priorities in the manufacturing and distribution of food products. The effectiveness of sanitation procedures had been evaluated using immediate visual assessments or microbiological methods such as hygiene swabs or agar contact plates (Griffith *et al*., 2000). Rapid hygiene monitoring methods such as adenosine triphosphate (ATP) bioluminescence are available to provide an estimate of total surface contamination in real time has been well documented (Hawronskyj and Holah, 1997). This technique does not require laboratory and specialized staff and can be used effectively in field conditions (Aycicek *et al*., 2006).

Hazard Analysis and Critical Control Points (HACCPs) concept was designed to prevent microbial, physical and chemical hazards in food for the space missions (Janevska *et al*., 2010). The HACCP system is a recommended approach to enhance food safety from farm to fork. There are suggestions that it could be used to assure

halal compliance (Bonne and Verbeke, 2008; Kohilavani *et al*., 2012; Kohilavani *et al*., 2013; Riaz and Chaudry, 2004a; van der Spiegel *et al*., 2012). With the help of HACCP, Halal Control Points (HCPs) can be identified to eliminate potential presence of haram (unlawful) components in the manufacturing of halal food products. Halal Control Points plan can be utilized to ensure both food safety and halal analysis of food products. This is based on the view that safe food and hygienic production is the base for halal production (Riaz and Chaudry, 2004a). Food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (CAC, 1997). As such, the term halal encompasses cleanliness and hygiene in food preparation because cleanliness is part of religion and Allah (S.W.T.) only permits hygiene, safe and halal foods or products for Muslims consumptions (Ambali and Bakar, 2014). Utensils, equipment and machinery (including all food contact surfaces) must be cleaned, sanitized and untainted by contact with haram materials (Henderson, 2015). For the identification of haram substance, zero tolerance practice is adopted to ensure that the religious requirements are stringently followed (Kohilavani *et al*., 2013). This study aims to determine the understanding of halal concept among food production workers, evaluate the hygiene and sanitation (via adenosine triphosphate (ATP) swabbing) and to develop a generic Halal Control Point (HCP) Plan for food processing.

Methods

Development of Questionnaires and Interview Questions

A semi-structured questionnaire (with both opened and close-ended questions) (Burgess, 2001) which include demographic profile, understanding and attitude towards halal food sections was designed. Statements such as 'I understand what is Halal'; 'Halal focuses on slaughtering only'; 'Halal focuses on slaughtering and food quality'; 'Halal food does not contain pork and alcohol' and 'Halal food must be prepared by Muslims' were included to capture a snapshot of understanding of halal concepts among food production workers. In-depth interviews related to the quality assurance and halal practices in food manufacturing plants were conducted among Quality Assurance staff. A pilot sample of 30 participants from a food manufacturing company was carried out. A sample of 30 participants from the population of interest is a reasonable minimum recommendation for a pilot study where the purpose is preliminary survey or scale development (Johanson and Brooks, 2009). Cronbach's

alpha is used as a measure of the reliability (≥ 0.70) of a set of questions in a survey instrument as it can measure the interrelatedness of a set of items (Cronbach, 1951).

Sampling

Two hundred respondents were targeted as the minimum sample size to ensure reliability (Yurdugul, 2008). Respondents (ethnic origins and religions were not taken into consideration to reduce biasness) were randomly selected from four different halal food manufacturing plants: Company A (soy sauce), Company B (frozen chicken roll), Company C (oat) and Company D (coffee powder). 150 respondents were from companies A and B and the remaining 50 from firms C and D. Although survey and interviews were conducted among workers from Company A, no swabbing tests were allowed. All organisations had been renamed as A – D to ensure anonymity.

Real Time ATP Hygiene Monitoring System and Microbiological Tests

Hygiena's SystemSURE Plus (Hygiena, Camarillo, CA, United States) ATP hygiene monitoring system was used to detect the level of hygiene in workers' and associated food preparation surfaces in the processing plants. Food contact surfaces and workers' hands (from lower palm to each fingertips) were swabbed during production and results were expressed numerically as Relative Light Units (RLU) (Hygiena, 2013). End products were collected from each food processing plants and transported back to the laboratory. Short shelf life product i.e. frozen chicken roll were transported in a carrier box containing ice packs and analyses were performed upon recept of samples at the laboratory. However, if a laboratory analysis was postponed due to delayed arrival of samples, the samples were refrigerated at 0 – 4˚C until examination but were not kept longer than 36 hours (Al Mamun *et al.,* 2013). 25 g of each sample were homogenised in 1% buffered peptone water in a Stomacher 400 Circulator (Seward, UK) blender for 2 minutes. Following homogenization, all samples were tested for total plate count.

Halal Control Points (HCPs)

In this study, HACCP and Halal Critical Control Points decision tree (Kohilavani *et al*., 2013; MS 1500: 2009) were adapted to identify and eliminate potential presence of haram components (Figure 1).

Figure 1. Decision tree to identify Halal Critical Control Points (HCCPs) in ingredients and process controls (Kohilavani *et al*., 2013; MS 1500: 2009)

Results and Discussion

Validation of Questionnaire

The pilot test questionnaires were analyzed and the value of Cronbach's alpha was 0.801. The higher the Cronbach's alpha coefficient is, the more correlated the items are within the relevant variable which theoretically should be higher than 0.700 (Pallant, 2005).

Demographics

Majority of the participants came from the age group of 31 to 40 years (40.00%) (Table 1). According to the Department of Statistics Malaysia (2015), the percentage of employed persons in 2014 showed that 76.20% of the persons employed were from the age group of 25 to 54 years old whereas minority (8.20%) were employees from age 55 to 64 years old. Furthermore, majority of the respondents (87%) had completed secondary education whilst 19% studied at upper secondary schools and above.

Table 1. Demographics of food production workers (N = 200)

Understanding and Attitude towards Halal Food Products

The respondents' understanding of halal principles is important in providing an insight into Malaysian consumers' attitudes toward halal products. In this case, 77 respondents (38.50%) claimed that they understand the concept of halal. In contrast, a minority of them claimed that halal foods must only be prepared by Muslims (X^2 = 50.95; df = 4; P < 0.05) (Table 2). Previous findings suggested that consumers generally perceive pork and alcohol to be haram (Salman and Siddiqui, 2011). Although participants have various responses towards this statement, these do not indicate that they have a poor understanding or misconception towards the concept of halal. (Nawai *et al*., 2007). In fact halal has now become a universal concept as

demonstrated in other similar studies (Ambali and Bakar, 2014; Henderson, 2015; Mohd Shariff and Abd Lah, 2014).

Table 2. Participants' single response towards the concept of halal (N=200)

Based on Table 3, 76.5% of the respondents (regardless of religion) demonstrated a positive attitude towards halal food products. Religious beliefs, food safety, animal welfare, environmentally friendly, age, education level and area of residence are significant determinants of the consumers' attitude towards understanding and awareness of halal principles and halal food products (Rezai *et al*., 2010). However, the behaviors of Muslims consumers are largely predisposed by their Islamic ideology (Salman and Siddiqui, 2011).

Table 3. Attitude of respondents towards halal food products (N=200)

ATP Swabbing Tests

Table 4. Adenosine Triphosphate (ATP) swabbing tests (N =12)

Company B revealed the highest average RLUs (233.5 ± 2.1) due to the presence of food debris and this is particularly related to the chemical composition of the organic residues present (Moore and Griffith, 2002). Investigation conducted in vegetable processing plant revealed that the surface of chopping board possessed 209 RLU (Kuisma *et al*., 2014). In contrast, the lowest average RLUs were recorded in Company C. This might be due to the implementation of HACCP and International Organisation for Standardisation (ISO) 22000 Food Safety Management Systems in the manufacturing plant. Food production workers' left and right hands (from lower palm to each fingertips) were swabbed as these areas can provide a suitable and sufficient surface area for swabbing (Yaembut *et al*., 2016). The highest mean RLU (96.5 ± 2.1) was recorded in workers from Company D. It is probable that the daily cleaning is not following the standard procedures. Similar ATP swabs were conducted domestically by Larson *et al*. (2003) with acceptable values (2.6 ± 0.8 RLU) (Larson *et al*., 2003) while Sudheesh *et al*. (2013) reported that all tested food contact surfaces failed the sanitation quality test with readings as high as 100,000 RLU. Aprons were

provided for food production workers which were changed on a daily basis. The highest mean RLU was found among workers from Company B. The lowest mean RLU reading was from Company C which has an integrated automated system to facilitate mechanical production of goods, and workers' aprons were less likely to be contaminated with food residues. In another similar study, Worsfold and Griffith (2001) found 96469.00 RLU on aprons and the ATP might had be derived from dead microorganisms, food residues or hand ATP. Primary or secondary packaging materials (plastic) were also swabbed. In this case, the recorded RLU readings for three companies were same, which was 0 RLU.

Halal Control Points (HCPs)

Hazard Analysis and Critical Control Points (HACCPs) is a Food Safety Management System (Al-Kandari and Jukes, 2011) which is widely acknowledged as the best method of assuring product safety whilst becoming internationally recognized as a tool for controlling food borne safety hazards (Khandke and Mayes, 1998; Wallace *et al*., 2005). In this study, HACCP was adapted with Halal Control Points (HCPs) to identify and eliminate potential presence of haram components. Based on Kohilavani *et al*. (2013) decision tree, survey and the interview results from the four food manufacturing plants, four specific HCPs plans were developed (SeeAppendix for Supplementary File Tables 1-4). The supplementary tables provide a halal analysis and justification for inclusion of the HCPs. This concept is similar to hazard analysis in HACCP.

Based on the four specific HCPs plans generated, a generic HCPs Plan was developed (Figure 2). It is useful as it can be used as a guideline in halal food industries with the purpose of identifying the possible sources of haram contamination.

Figure 2. Generic Halal Control Points for food industries

HCP 1: Halal Certification

When importing raw materials from foreign countries, the manufacturer sends representative to the supplier's site to conduct audit. This includes inspecting the implementation of halal practices in the premises, quality of the raw materials and

halal certification. Today, many Muslims countries require food products imported to their countries be certified halal (van der Spiegel *et al*., 2012). In order to get halal certification, inspection of the facility, review of sanitation, ingredients and labels and training the company personnel are important (Riaz and Chaudry, 2004b).

HCP2: Equipment

For the company producing non-meat products, it is sufficient to clean equipment and determine cleanliness by visual observation. If food premises producing halal food carry out haram operations, it is required to perform a mandatory ritual cleansing (Man and Sazili, 2010). Besides, chemicals used for cleaning should be screened to avoid animal fat origin (Riaz and Chaudry, 2004a) and the brushes should be halal certified as it can be made out of pigs' hair (Fischer, 2015).

HCP3: Raw materials/ingredients

The halal status of ingredients derived from plant origins is rarely an issue except it is from animals (Riaz and Chaudry, 2004a). Flavours and flavourings contain several ingredients that can be derived from microorganisms, plants, minerals, petroleum, animals and synthetic sources. So, the manufacturer has to make sure that any flavours, proprietary mixes or secret formulas are halal and free from doubtful materials (Riaz and Chaudry, 2004a).

HCP4: Transportation and storage

Often, the manufacturer takes charge of the shipping and storage condition or they rely on the vehicles of buyers in the distribution of goods. The vehicles used to transport goods must be cleansed thoroughly and avoided from shipping food products which could emit pungent odor such as onion or garlic. The storage condition should also be inspected by the related staff to ensure the freshness of the food products. During transportation, halal foods must be handled properly to avoid cross-contamination with haram products.

Microbiological Analysis

No microorganisms were detected in food samples such as frozen chicken roll, oat and coffee powder but the TPC found in soy sauce was 4.8 ± 5.1 log CFU/mL. Yan *et al*. (2013) conducted an enumeration of microbiota present during koji-making in soy

sauce production found that the total mesophilic aerobic bacteria (TMAB) was 8.8 log CFU/g. In this study, the microbial load was much lower compared to Yan *et al*. (2013) which may be attributed to the heat treatment applied on the soy sauce after passing through the koji-making process. Soy sauce was found to initiate the growth of purple mucoid colonies on Eosin and Methylene Blue (EMB) Agar. The absence of green metallic sheen suggested that *Escherichia coli* was absent as Eosin methylene blue agar provides a rapid and accurate method to identify *Escherichia coli* (Leininger *et al*., 2001; Macfadden, 1985) Primary screening test was performed and the suspected colonies were from the family of Enterobacteriaceae (Singh *et al*., 2015). Previous studies revealed that nine species belonging to the family Enterobacteriaceae were identified in the fermentation of inyu (Wei *et al*., 2013) and koji (Yan *et al*., 2013).

Conclusion

The findings indicated that food production workers in general demonstrated an understanding and positive attitude towards halal food products. In terms of hygiene and sanitation of the manufacturing plants, the ATP swabbing tests of food contact surfaces (tabletops) revealed that only two companies passed the swabbing tests (≤ 10 RLU). The ATP swabbing tests for all workers' hands and aprons did not meet the hygiene requirements (> 30 RLU). Based on the interviews conducted with quality control staff, Halal Control Points (HCPs) were identified in the manufacturing process of food products, and one generic HCPs plan and four specific HCP plans were developed for the manufacturing process of halal food products for each food company.

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Appendix

Insert Supplementary file tables 1-4 (four tables)

Table 1. Demographics of food production workers (N = 200)

Demographic items	*N* (%)
Age	
≤ 20	None
21-30	73 (37)
31-40	80 (40)
41-50	36 (18)
≥ 51	11 (6)
Position	
Manager	4 (2)
Production worker	140 (70)
Quality assurance/executive	9 (5)
Research and development executive	8 (4)
Supervisor	9 (5)
Others	30 (15)
Number of years working in food industry	
≤ 5	103 (52)
6-10	59 (30)
11-20	33(17)
≥ 21	5 (3)
Academic qualification	
Primary level	None
Lower secondary level	40 (20)
Secondary level (O levels)	87 (44)
Upper secondary level (A levels)	2 (1)
Diploma/Degree/Master/PhD	36 (18)
Others	35 (18)

Notes: N represents the number of respondents; (%) represents their share in the sample.

Table 2. Participants' response towards halal concepts (N=200)

Understanding of halal concepts:	*N* (%)
I understand what is Halal	77 (39)
Halal focuses on slaughtering only	24 (12)
Halal focuses on slaughtering and food quality	32 (16)
Halal foods do not contain pork and alcohol	45 (23)
Halal foods must be prepared by Muslims	22 (11)

Notes: N represents the number of respondents; (%) represents their share in the sample. Chi-square test has been performed (X^2= 50.95) and all statements are significantly different at the level of 5%.

Table 3. Attitude of respondents towards halal food products (N=200)

Statement	*N* (%)
I emphasized the halal status of food products that I purchased[a]	
Strongly disagree	0
Disagree	0
Neither agree nor disagree	47 (24)
Agree	95 (48)
Strongly agree	58 (29)
Religious obligation is a major concern of mine when purchasing food products[b]	
Strongly disagree	0
Disagree	0
Neutral	54 (27)
Agree	97 (49)
Strongly agree	49 (25)
Halal principle is related to hygiene and food safety[c]	
Strongly disagree	0
Disagree	0
Neutral	50 (25)
Agree	93 (47)
Strongly agree	57 (29)
Knowing how halal food is produced or processed is very important[d]	
Strongly disagree	0
Disagree	0
Neutral	55 (28)
Agree	100 (50)
Strongly agree	45 (23)

Notes: N represents the number of respondents; (%) represents their share in the sample (five-point Likert scale: 1 = "strongly disagree", 3 = "neutral", 5 = "strongly agree"). Chi-square test has been performed to compare the statements of respondents towards halal food products. Items denoted with superscripts represent the X^2 values (a = 18.97; b = 20.89; c = 15.97; d = 25.75) and all statements are significantly different at the level of 5%.

Table 4. Adenosine Triphosphate (ATP) swabbing tests (N =12)

Area being swabbed	**Company (Reflective Light Unit [RLUs] of contact surfaces)**			
	A (soy sauce)	B (chicken roll)	C (oat)	D (coffee powder)
Preparation tables	-	Fail (233.5 ± 2.1)	Pass (1.0 ± 0)	Pass (2.5 ± 0.7)
Workers' hands (left and right hands – swabbed from lower palm to each fingertips)	-	Fail (82.0 ± 2.8)	Fail (73.0 ± 1.4)	Fail (96.5 ± 2.1)
Workers' aprons	-	Fail (84.5 ± 0.7)	Fail (56.5 ± 2.1)	Fail (67.0 ± 1.4)
Packaging materials	-	Pass (0)	Pass (0)	Pass (0)

Notes: N represents the number of swab samples. The calculated values are expressed as mean values of triplicate samples ± standard deviation. Swabbing tests were not permitted in Company A. Pass: Any score of 10.00 RLU or less; Caution: Scores from 11.00 to 30.00 RLU; Fail: Any score greater than 30.00 RLU

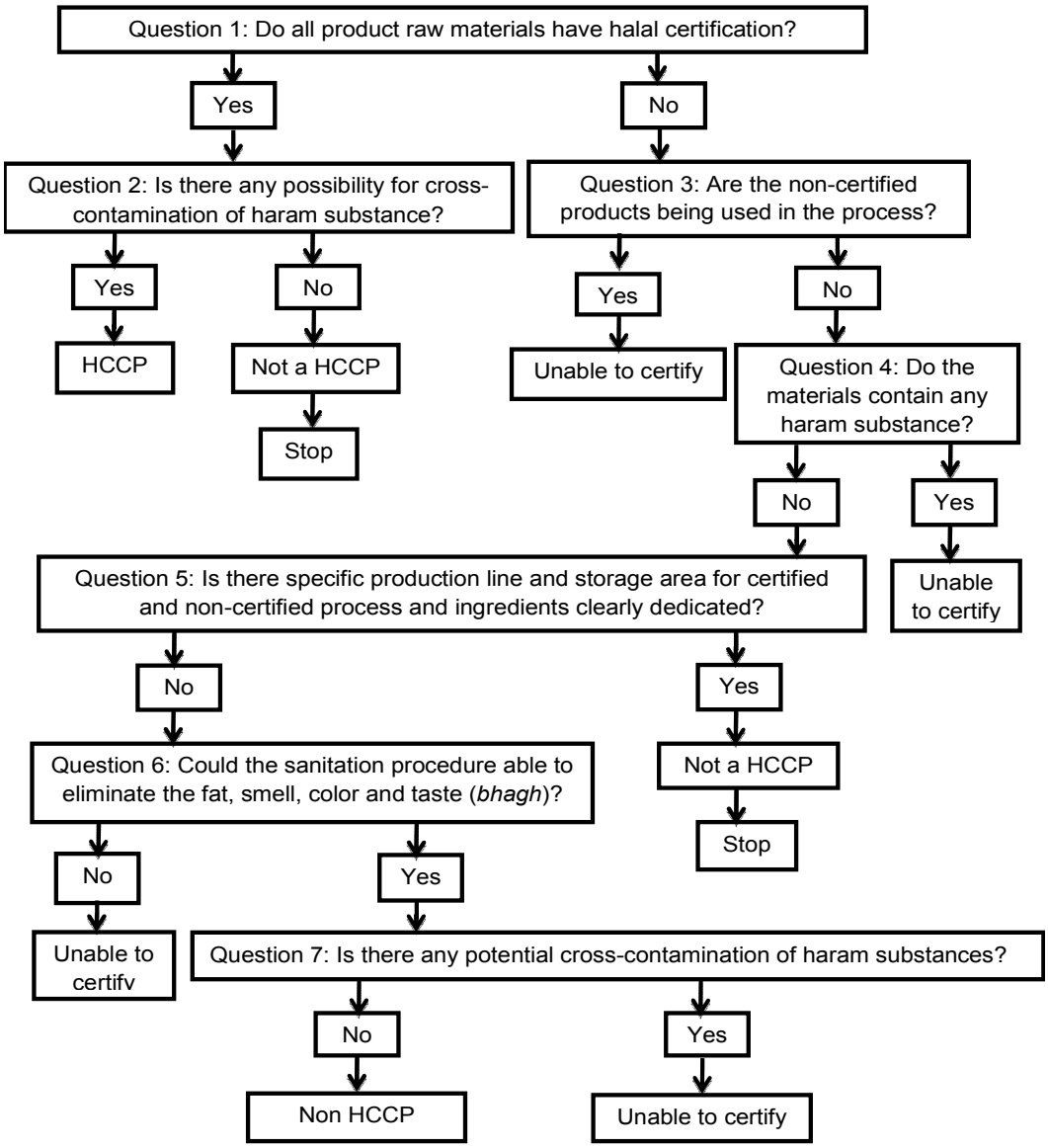

Figure 1. Decision tree to identify Halal Critical Control Points (HCCPs) in ingredients and process controls (Kohilavani *et al*., 2013; MS 1500: 2009)

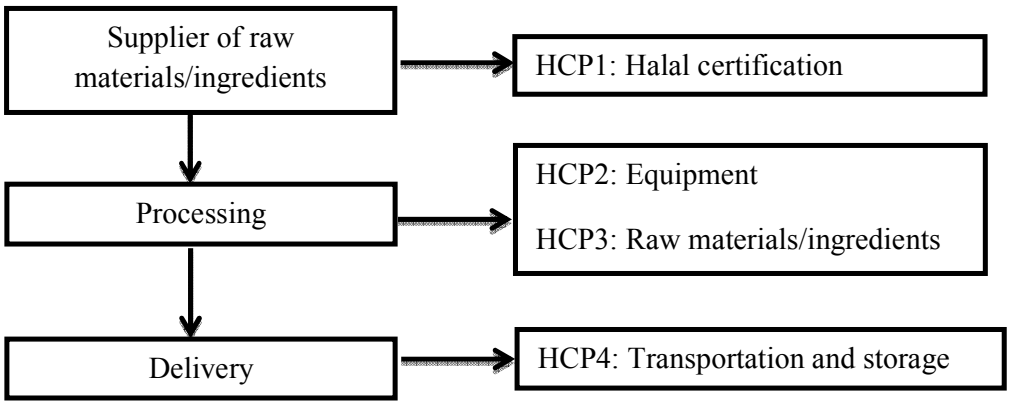

Figure 2. Generic Halal Control Points (HCPs) for food industries (See Supplementary Files Tables 1 – 4 for halal analysis and identification of HCPs)

Supplementary File Table 1. Halal analysis and identification of Halal Control Points (HCPs) in production of soy sauce

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Selection	HCP 1	Potential for transport or storage contamination with non-halal products	Suppliers to provide halal certifications or conduct suppliers' second party audit to verify storage of soy beans and incoming goods check
Koji / Moromi	HCP 2	Potential for mixing with non-halal products such as alcohol to enhance the flavour and taste of soy sauce	Quality control performed by related trained staff in halal certification
Refined soya sauce	HCP 3	Potential of entrance of non-halal products into the final product	Quality control performed by related trained staff in halal certification
Delivery	HCP 4	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 2. Halal analysis and identification of Halal Control Points (HCPs) in production of frozen chicken roll

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receipt of halal chicken	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification
Production	HCP 2	Potential for mixing with non-halal ingredients such as lard which has been commonly used to replace oil	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 3. Halal analysis and identification of Halal Control Points (HCPs) in production of oats

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receiving	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification or conduct supplier second party audit to verify storage of oat and incoming goods check
Kilning	HCP 2	Potential for mixing with non-halal products (cheaper raw materials and ingredients)	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification

Supplementary File Table 4. Halal analysis and identification of Halal Control Points (HCPs) in production of coffee powder

Process steps	Halal Control Points (HCPs)	Justifications	Preventive measures
Receiving	HCP 1	Potential for transport or storage contamination with non-halal products	Supplier to provide halal certification
Roasting 1 / 2	HCP 2	Potential for mixing with non-halal products (cheaper raw materials and ingredients) in the open roaster	Quality control performed by related trained staff in halal certification
Delivery	HCP 3	Potential for transport contamination with non-halal products	Transports were cleaned and inspected by related trained staff in halal certification